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BUREAU OF MINES
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GUARDING TROLLEY WIRES IN MINES

BY

E. J. GLEIM

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GUARDING TROLLEY WIRE IN MINES[1]

By E. J. Gleim[2]

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INTRODUCTION

Contact with trolley wire in the mines of the United States has taken a considerable toll of life throughout the years that trolley locomotives have been employed as a means of transportation. A study3/ of the records over a 15-year period for one State alone showed that, of 98 fatalities resulting from contacts with electrical circuits and equipment, 75 were caused by direct or indirect contact with unguarded trolley wire in coal mines. The law relating to guarding trolley wires in the mines of this particular State, as amended in 1935, reads in part as follows: "All trolley wires carrying 220 volts or more, and less than six feet six inches above top of rail, must be guarded at all points under which men and animals are required to pass***." The natural conclusion to be drawn from such records is that lack of guards or shields must be held responsible for these fatalities. As a preventive measure, it has been advocated that every foot of trolley wire in mines should be guarded. Although some such drastic steps may appear to be amply justified, closer examination of the records for this and other coal-mining States shows that absence of guards is not entirely responsible, but rather that other factors, such as carelessness and neglect in the observance of certain well-established simple rules concerning installation and location of trolley wires, also are responsible. In other words, if trolley wire is installed carelessly and its maintenance is neglected, it should not be expected that the mere installation of guards will overcome such carelessness and neglect.

This publication discusses various types of guards that have been used in coal and metal mines of this country, together with related steps bearing upon the problem of preventing shock and fatalities from contacts with trolley wire. The material herein contained is taken largely from Information Circular 6577,4/ now out of print, and has been revised to include some types of guards that have been used in metal mines, together with a discussion of guard materials not covered in that publication.

Along with the installation of guards, a number of factors affect safety as related to trolley wires in mines. Most important in any effort to reduce contact hazards are the following:

1. Installation of trolley wires in relation to track and passageways.

2. Materials and construction of guards.

3. Maintenance of trolley circuits and guards.

4. Discipline to discourage unsafe practices.

3/ Cash, F. E., Fatalities Caused by Electric Contacts in Alabama Coal Mines, 1925-39: Bureau of Mines Inf. Circ. 7120,1940, 20 pp.

4/ Gleim, E. J., Guarding Trolley Wires in Mines: Bureau of Mines Inf. Circ. 6577, 1932, 11 pp.

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ACKNOWLEDGMENTS

Helpful suggestions and information supplied by mining-electrical engineers and others of the Coal Mine Inspection and Safety Divisions of the Bureau of Mines for use in this revision are gratefully acknowledged.

INSTALLATION OF TROLLEY WIRE

The statement that all fatalities should not be charged to lack of guards is supported by the following example: A man operating a locomotive was electrocuted when the trolley wheel jumped off the 250-volt trolley wire and allowed the wire to sag against his shoulder. He was sitting in the regular place provided in the locomotive, but at the point where the wire touched him it was 11 inches inside of the rail and only 39 inches above it, or 11 inches from the roof at a distance of 12 feet from the nearest hanger. The accident occurred between two hangers that were 44 feet apart, and the trolley wire was inside the rail over the entire distance, being 2 inches inside at one hanger and 10 inches inside at the other. A bolt in the roof indicated that at one time a hanger had existed between the two in the 44-foot span.

This example is cited as a violation of good practice in the installation and maintenance of trolley wire. In the first place, the wire should have been outside instead of inside the rail. In the second place, there should have been at least one intermediate hanger, so that the span would not be so great and the sag would be reduced. Furthermore, it is possible that the wire was not taut enough even if an intermediate hanger had been in place.

Laws Governing Installation

Recognizing that a degree of safety can be achieved if trolley wires are correctly placed initially, a number of States have enacted laws to regulate the installation of such wires. Although some of the codes are rather brief in this respect, others are quite detailed. The mining laws of Ohio (effective September 2, 1941) may be cited as an example of a code in which the installation of trolley wires is covered in considerable detail, as follows:

> All trolley and feed wires shall be placed on the opposite side of track from refuge holes or necks of room ***. Inside the mine the trolley wire shall be installed parallel to the gauge line of the rail and as far away as practical and in no place closer than six inches from the gauge line, except where written permission is given by the chief, division of mines. It shall be securely supported on hangers efficiently insulated. Such hangers shall be placed at intervals of not exceeding thirty feet and at less intervals if it may be necessary to do so to prevent the sag between points of support exceeding three inches. Hangers hereinafter installed shall be of sufficient height to place the trolley wire within six inches of the roof or cross timbers at

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the point of trolley wire support, except in such places as the trolley wire may be above the normal seam or draw slate taken with the seam or six feet six inches from the top of rail.

The primary object to be achieved by laws such as the foregoing is to minimize exposure to contacts (1) by keeping the trolley wire at one side of the track, rather than above it, so that men in cars or walking along the track will not have the wire directly over their heads; (2) by keeping the wire away from that side of the haulageway where men are most likely to travel and away from the side where refuge holes have been provided for men to enter during the passing of trips, and (3) by keeping the wire at a uniform height above the rail with a minimum of sag.

If, in the case mentioned, the trolley wire had been installed in accordance with the foregoing law, it is altogether probable that a life would not have been lost, because the wire would have been at least 17 inches further away from the center of the track and possibly 5 inches higher above it.

Company Rules for Installation

There are some details concerning good practice in installation which the State laws do not cover, and therefore, in order to obtain uniform construction consistent with safety, some coal companies have developed a "standard" to be followed by wire men in all their mines. For instance, the Union Pacific Coal Co. has a "Code of Standards," illustrated by a drawing, which includes the following rules:

1. Trolley wires shall be No. 4-0 B and S gauge grooved, and shall be supported on hangers of Type _____, Cat. No. _____ or equivalent.

2. The height of the trolley wire above the rail shall be made as uniform as practicable.

3. Trolley wires shall be placed so as to give the maximum practical clearance and shall be kept in as straight a line as possible. They shall have a maximum height of not to exceed 6-1/2 feet and a minimum of not less than 4 feet.

4. On straight runs, the hangers shall be placed not more than 20 feet apart where the height of roof above the track is 5 feet or less and not more than 25 feet apart where the roof is more than 5 feet above the track. On curves, the hangers shall be placed so close together that the trolley wire at any one hanger may be entirely disconnected without exposing the locomotive runner to danger of contact.

The illustration accompanying these rules shows the trolley wire to be "6-1/2 feet if possible" above the rail and 6 inches outside. A

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clearance alongside the other rail is also shown "to be not less than 34 inches from rail on one side of all haulageways." Beside the illustration is the noteworthy statement: "The haulage system of a mine is so important that it is necessary to install all feeder and trolley circuits in a safe manner." It is evident that with a 34-inch space in which to walk on the side of the track opposite that on which the wire is placed, there is no reason why a man on foot should come in contact with the wire unless he is required to work on the track or wire or in connection with derailed cars, or unless he crosses underneath the wire.

American Engineering Standards

Besides the rules and regulations drawn up by company and State organizations, there are certain rules that were jointly sponsored by the American Mining Congress and the Bureau of Mines and adopted by the American Engineering Standards Committee as American Standard on October 8, 1926. For the purpose of comparison, those rules bearing on trolley-wire installation are given:

> (82) Trolley wires shall be hard-drawn copper not smaller in size that 1/0 B. & S. gage and shall be securely supported on approved hangers, which may be attached directly to the roof or securely fastened to timber or equivalent.
>
> (83) The height of trolley wires above the top of the rail shall be made as uniform as practicable and shall in no case be more than 20 percent above or 20 percent below the average height.
>
> Trolley wires shall be placed at least 6 inches outside of the rail, kept in as straight a line as possible, and installed on the side of the entry opposite from shelter holes or traveling way or space.
>
> On straight runs the hangers shall be spaced not more than 20 feet apart where the height of the roof above the track is 5 feet or less and not more than 30 feet apart where the roof is more than 5 feet above the track. On curves the hangers shall be spaced so close together that the trolley wire at any one hanger may be entirely disconnected without exposing the locomotive runner to danger of contact.

GUARDING

It is obvious to mining men that even when favorable conditions permit placing the trolley wire at a good height above the rail and at the side of the track, there is still no complete assurance that men and animals will not in some way make contact with that wire. The first step in preventing such contacts is to install the trolley wire where it will be farthest from the normal path of men traveling in the mine. A second and more effective step in the direction of prevention is assured when the wire

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is guarded at room necks, loading chutes, doors, man-trip stations, and similar fixed points where men must pass beneath or near it. However, a study of the records of some of the coal-producing States covering accidents from electricity over a period of several years indicates that a still greater degree of protection against shock is highly desirable. The wireman, the pumper, the track worker, the man cleaning the roadway, and the man replacing derailed cars and locomotives - in other words, any man who may have to work under or near the trolley wire at any place throughout its length - must also receive consideration, as well as the man who merely passes along the haulageway in going to or leaving his place of work. Therefore, as long as the bare trolley wire is an essential part of the haulage system in a mine, it must be shielded along its entire length if this still greater measure of protection is to be achieved.

There appears to be no mine law as yet that requires full-length guarding of trolley wires, and while most of the State codes in which guarding is required exempt wires that are 6-1/2 feet or more above the rail, there is one State (Texas) where the wire may be as low as 5-1/2 feet without shielding. With this one exception, it is evident that those who originally framed the laws commonly regarded 6-1/2 feet as ample space to allow a miner to pass underneath wighout danger of contact with the wire. However, it is not apparent that this height was intended to allow any clearance for metal tools or materials he might be handling or carrying, although at least one coal-mining State has increased the distance to 7 feet for new installations.

The following paragraphs show the scope of the various rules and regulations that have been drafted for insuring some measure of protection against contact with trolley wires.

Laws and Rules Relating to Guards

The mine laws of the various States differ considerably with respect to guarding trolley wires. In some codes, no specific requirement for guards is made, whereas others contain only a general statement on guarding. An example of the latter from a 1940 code of Oklahoma states:

> All wires conducting electricity in and about said mines shall be carefully and thoroughly insulated or protected in a safe manner so that all persons or animals coming in contact therewith shall not be injured thereby. All wires as aforesaid, shall either be insulated or placed where persons employed in and about the mine cannot come in contact therewith or shall be covered, protected, or sheltered in a safe manner so as to prevent accidents therefrom to those in and about the mine.

Although the intent of such phrasing is clear, questions of interpretation may arise in deciding whether a certain trolley wire has been "covered, protected, or sheltered in a safe manner." Other State laws go

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into considerable detail, leaving little to the personal judgment of individual inspectors regarding places where wires are to be guarded or what features of construction are acceptable. An example of such a law is to be found in the bituminous mining laws of Pennsylvania as amended in 1937, which reads as follows:

> At all landings and partings, or other places where men are required to regularly work or pass under trolley or other bare power wires, which are placed less than six and one-half feet above top of rail, a suitable protection shall be provided. This protection shall consist of placing boards along the wire, which boards shall not be more than five inches apart nor less than two inches below the lowest point of the wire: Provided, That the distance between boards on curves may exceed five inches, but shall not exceed eight inches. This does not prohibit the use of other approved devices or methods furnishing equal or better protection.

Some framers of mining laws have considered guarding to be particularly necessary at certain points "where men are required to regularly work or pass under trolley and other bare power wires." Thus, in the Utah General Coal Mine Safety Orders, effective July 1, 1937, we find that "At all points where timbers or tools have to be unloaded or transferred up a raise, and in front of chutes from which rock or coal is being drawn, the trolley wires shall be boxed or otherwise protected as provided for in this paragraph." Also, in the coal-mining laws for Alabama, as amended in 1935, it will be found that "All trolley wires carrying 220 volts or more, and less than six feet six inches above top of rail, must be guarded at all points under which men and animals are required to pass and, regardless of height, at stations designated for the loading and unloading of man-trips; and at sand-boxes." The Electrical Safety Orders, effective May 1, 1934, and applying to "mines, tunnels, and similar locations" in the State of California, require:

> Trolley wires within 8 feet horizontally of the sides of loaders or of chutes or platforms shall be guarded by nonconducting guards on both sides of the trolley for at least 4 inches above and 4 inches below the wire at the lowest point of sag. The sag between supports of the trolley wire shall not exceed 3 inches. The guards shall be so installed and maintained that they will not come into contact with the trolley wires and so that the opening between their lower edges does not exceed 6 inches on curves or 4 inches on tangents.

The orders and laws just quoted take cognizance of the fact that there are locations and circumstances under which special measures must be taken to reduce contact hazards.

The code of standards drawn up by the Union Pacific Coal Co. contains the following rule:

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Trolley wires that are less than 6-1/2 feet above the top of the rail shall be protected at all points where men are regularly required to work or pass under them, and at all points where the men may come in contact with the wires.

The American Standard relating to guards reads as follows:

Trolley wires that are less than 6-1/2 feet above the top of the rail shall be guarded at the point where men are daily required to work or pass under them.

Bureau of Mines "Tentative Bituminous and Lignite Mine Inspection Standards,5/ which are used as a guide in the Federal inspection of such coal mines, contains the following references to guarding of trolley wires:

Section 18, Item 60. If there is any hazard of men contacting the trolley wire, at man-trip loading and unloading stations, the power should be cut off while men are loading and unloading; also, the wire should be adequately guarded at these stations.

Section 19, Item 35. Trolley and bare power wires should be: *** (g) Adequately guarded where men are required to pass under the wire, unless the wire is 6-1/2 feet or more above the top of the rail.

(h) Adequately guarded and sectionalized at man-trip stations.

(i) Adequately guarded throughout unless the wire is 6-1/2 feet or more above the top of the rail.

Section 19, Item 37. Power and trolley wires should be properly guarded on both sides of all doors.

The Bureau's "Tentative Inspection Standards for Anthracite Mines"6/ contains three standards that are almost identical with the foregoing, namely, those calling for guards (1) at man-trip loading and unloading stations, (2) where men are required to pass under the wire, unless the wire is 6-1/2 feet or more above the top of the rail, and (3) on both sides of all doors.

The laws and rules just quoted would seem to furnish a reasonable basis for determining where guards are needed most. From them, a list of places may be prepared which should received first consideration in any program of guarding in mines where wires are not guarded throughout. They are as follows:

5/ Bureau of Mines, Tentative Bituminous and Lignite-Mine Inspection Standards: Inf. Circ. 7268, 1943, 54 pp.

6/ Bureau of Mines, Tentative Inspection Standards for Anthracite Mines: Inf. Circ. 7282, 1944, 48 pp.

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1. At both sides of doors.

2. At all stations where man-trips are loaded and unloaded.

3. At all points where timbers, other materials, and tools have to be transferred up a raise.

4. In front of all chutes from which coal or rock is being drawn.

5. At sand boxes.

6. At all points where men and animals are required to pass under wires that are not at least 6-1/2 feet above the top of the rail.

Many mining men seem to consider that guarding bare power wires, including the trolley wire, at the main intersections or similar places where men pass under them is sufficient protection; but there have been hundreds of fatal contacts with unguarded bare power wires at other points where men moving or coupling cars or rerailing them, or the motorman or his helper for some reason or other, have come in contact with the bare unguarded power wire. Power lines should always have well-grounded armored covering and in long-lived entries or levels should be placed in recesses in the rib or in conduits buried below the floor level.

Numerous metal mines and many coal mines have installed and maintained continuous guards for trolley wires, consisting of side boards or split rubber hose, throughout the trolley haulage roads and have been amply repaid by the resultant freedom from accidents caused by contact with the trolley wires.

In most mines it may be now impracticable to carry out complete guarding of trolley wire because of material shortage, labor shortage, and cost. However, it should be possible in an individual mine to start a program of adequately guarding exposed wires and extend such guarding as material and labor become available.

Types of Guards

Examination of the mining laws of many of the coal- and metal-producing States reveals no hard and fast rule concerning the type of guard that shall be used for preventing contact with trolley wires. The laws of 5 of 18 coal-mining States require boards or other approved devices, thus allowing considerable latitude in the choice of guard.

Many different materials have been tried in the construction of trolley guards, including wood, hard-pressed board, split hose, rubber belting, sheet rubber, and brattice cloth. Therefore, some discussion of these materials and arrangements for installing them may be of interest to those who are considering the merits of available materials.

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Wooden Guards

By far the most common type of guard in use seems to be that consisting of wooden boards held alongside the wire, the lower edges being even with or an inch or more below it.

In some mines the roof is drilled and pegs are driven into the holes to provide nailing surfaces upon which to fasten boards, which are about 1 inch thick and generally 4 to 6 inches wide. Such an installation has several disadvantages, one of which is that it makes a rigid construction that is probably more difficult to maintain than one that will yield when struck by trolley poles, roof falls, etc. When the boards are nailed on the far side of the pegs with respect to the trolley wire, they must be farther apart to give proper clearance between the trolley wheel and the pegs. This, in turn, would make it advisable to use a wider board to extend further downward and so obtain the protection equivalent to that obtained with narrower boards placed closer together.

Instead of driving pegs into the roof, it has become quite general practice to use various forms of hangers made of strap iron and drilled for the bolt that holds the trolley-wire clamp to the roof. One of these is shown as type A in figure 1. In this, the upturned hook portions hold the board without the necessity for nails or screws to fasten the board in place. This makes a guard that is easily installed and is preferred over many other types because there are no parts to loosen and allow the board to drop out. In the illustration, one board has been omitted so that the shape of the hangers can be seen clearly. The disadvantages of this design is that the spread between the vertical parts adjacent to the trolley wire must be such that the trolley wheel or harp cannot bridge the gap between the wire and the guard hanger and cause a short circuit when the wheel jumps the wire.

Two variations of this type of hanger are seen in types B and C, figure 1. In the first of these, the boards rest upon a ledge formed at the ends of the strap iron and are held in place by nails. In the second type, the strap iron is not drilled for nails, but, instead, the guard boards are secured by a cleat with a notch in it to fit around the strap iron. These two types of hangers possess the desirable feature of keeping the metal on the outside of the boards rather than on the inside, as was objected to in the type-A design.

The foregoing types have been simplified at some mines by omitting the hook and ledge portions, as may be seen by reference to types D and E. The only practical difference between these two is in the manner of fastening the boards. In the first, nails are used and in the second, bolts and nuts hold the boards. Type E has been seen in a mine with the boards outside, but by increasing its spread either type can be made so that the boards will be inside and thus cover the metal of the hanger. Unless the ends of the bolts are riveted over to prevent loss of the nut, it would seem preferable to have the head of the bolt on the outside so that the bolt could not move inward and obstruct the passageway for the trolley wheel and harp in case the nut loosened and dropped off.

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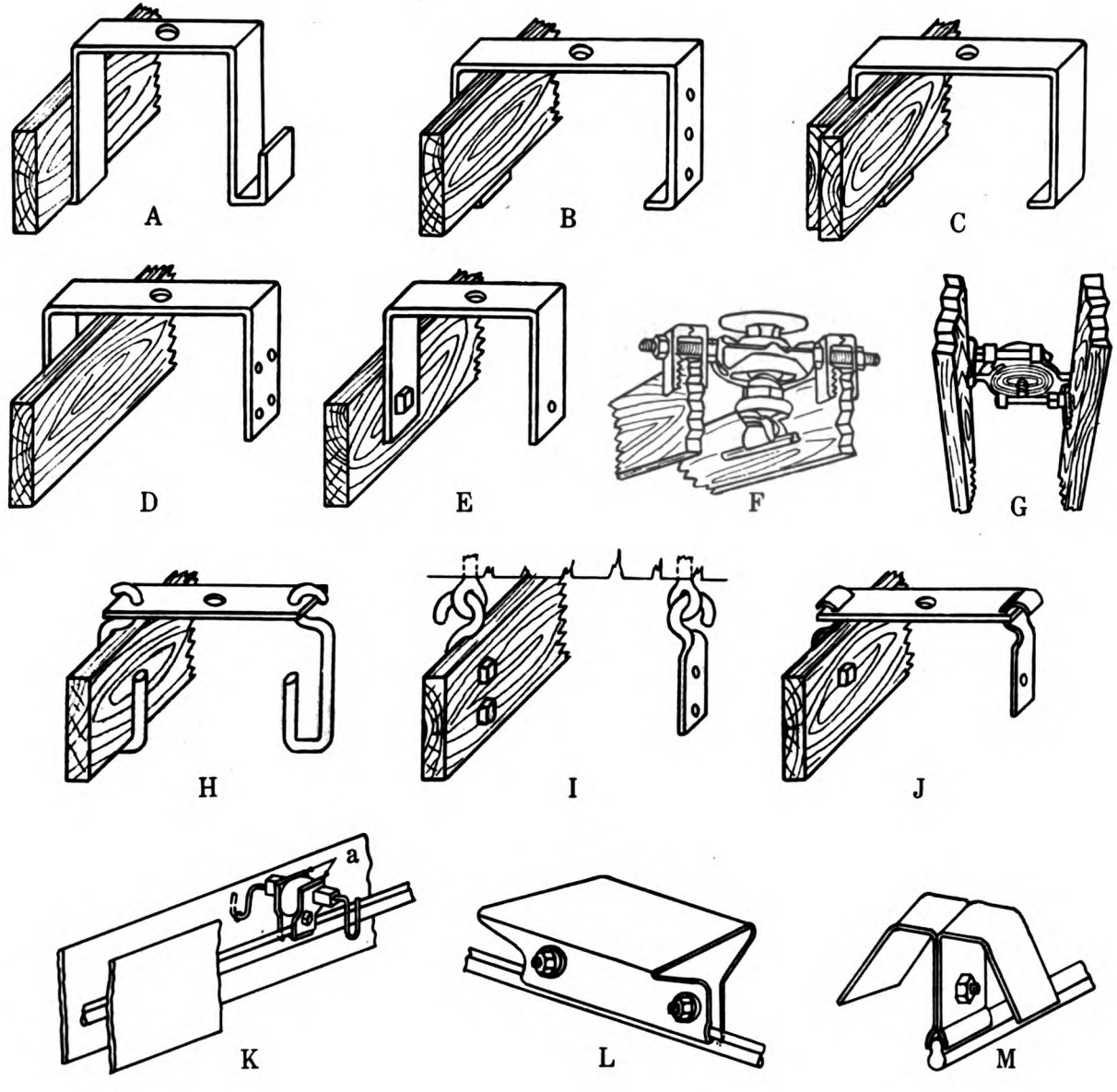

Figure 1.—Some types of trolley guard hangers.

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The five types just described are usually the product of the blacksmith shop at the mine. Two commercial types, however, that may be obtained on the market are illustrated in types F and G. Type F is for new trolley installations. In the former, the head of a short bolt is placed in a slot at the side of a special mine hanger and is held in place by a nut. The remaining length of bolt serves to support two toothed jaws or clamps that are closed upon the wooden guard board by tightening a second nut. In this way, the board is suspended from above and depends largely upon the tightness of the outside nut to keep it from dropping out. Type G consists of two main parts, which encircle the lower part of the skirt of the hanger shell. The two bolts used to make the two parts grip the shell are long enough to allow the use of the same clamping jaws as are employed with the type-F hanger. An arrangement that is optional with either type is obtained by omitting the clamping jaws and simply drilling holes in the boards and placing them on the bolts, after which a nut can be tightened down on the boards at each hanger. This requires a slightly wider board.

All of the proceding types are rigid - that is, the boards are at a fixed distance apart from each other and from the trolley wire and do not yield to blows from flying trolley poles or from falling coal and slate except through the natural electricity of the lumber itself. Furthermore, the rigid type does not close over the trolley wire when bumped with the head or a tool. It was, no doubt, in an effort to overcome these objections that the nonrigid types were developed, as seen in different mines and as shown in figure 1 as types H, I, and J.

Type H is made from round iron stock with two hooks, one of which is shaped to hold the board and the other is made into an eye that is looped through a hole drilled near the end of a piece of flat strap iron. The latter is supported by the trolley-wire clamp in the same manner as the types previously described. This design allows the boards to swing when struck. The amount of movement toward the wire, however, would have to be limited to keep the hooks from swinging against the trolley wire.

The type-I hanger also is made from round stock that has been flattened at one end and drilled for two bolts that hold the guard board. The other end of the piece of stock is formed into a hook that fits into an eye driven into the mine roof. Except for the nuts and the bolt ends there is no metal on the wire side of the board.

Another style of guard-board hanger that allows the boards to swing is that illustrated as type J. The part by which the board is suspended is made of flat stock. It is drilled for one bolt and is narrowed at the end that is bent to form a hook fitting into a slot in the end of the supporting strap.

Types H, I, and J guards require careful proportioning of the supporting hooks and proper location of the fastening bolts so that they will not touch the trolley wire when the guard swings; otherwise, there may be short circuits or exposed live bolt heads. Furthermore, it will,

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no doubt, be appreciated that these swinging types of guards require fairly close alinement and loose fits at the points that act as hinges if freedom of movement is to be obtained. Such close attention to alinement and fit may be obviated in a measure by adopting a method of suspension seen in use in one coal mine. This guard was made by putting screw eyes into the edge of the board and then at each screw eye taking a short piece of copper wire, about No. 6 gage, putting one end through the screw eye, and fastening the other end around the head of a rail spike which is driven into the mine roof.

The board-type guard implies the use of a board 4 to 6 inches or more in width, although most of the types described can be made to take narrower boards than this. In low seams, where every inch of clearance height is valuable, the wider boards are undesirable. In one mine where the height of coal was about 4 feet, the usual board-type guard was not used, but instead the wire was guarded by fastening 2- by 4-inch lumber to the roof with lag screws, the 4-inch face of the wood being against the roof. With such a guard the wood did not extend below the wire, that is, the lower part of the wire was about even with the lower edges of the wood. In addition, a short wire clamp was used, and it is questionable whether the arrangement allowed for adequate insulation of the trolley wire from the roof. Although the wire was not up between the two-by-fours, the guard would prove fairly effective, in that men approaching the wire would generally come in contact with the wood before the wire could be touched. A smooth, uniform roof would seem to be essential to the successful installation of such a guard.

Portable or Temporary Guards

Where a temporary or movable guard is required, one of the types indicated in figure 2 may be found suitable. Type A, described in the February 1932 issue of the Mining Congress Journal,7/ consists of two pieces of 2- by 4-inch oven-dried fir or pine that have been soaked in hot paraffin and coated with waterproof paint after assembly. A 5/16- by 5/8-inch matching groove is cut lengthwise in each piece, thus making a 5/8-inch square hole through the center of the assembled two pieces, as indicated, forming a complete enclosure for the trolley wire. This arrangement permits easy attachment and removal to allow for passage of locomotives or transfer to new locations. It has been used in a western copper mine. Another type also used in metal mines is that shown as type B in figure 2. In one form, and described in Bureau of Mines Information Circular 6546,8/ two L-shaped pieces cut from nominal 2- by 4-inch lumber are fastened together, so that the assembly can be hooked over the trolley

7/ Manning, R. I. C., and Forbes, J. J., Safety Cut-Outs for Trolley Wires at Underground Chutes: Min. Cong. Jour., vol. 18, 1932, pp. 24, 25, and 28.

8/ Manning, R. I. C., and Tallon, A., Safety At the Old Dominion Copper Mine, Globe, Ariz.: Bureau of Mines Inf. Circ. 6546, 1931, 41 pp.

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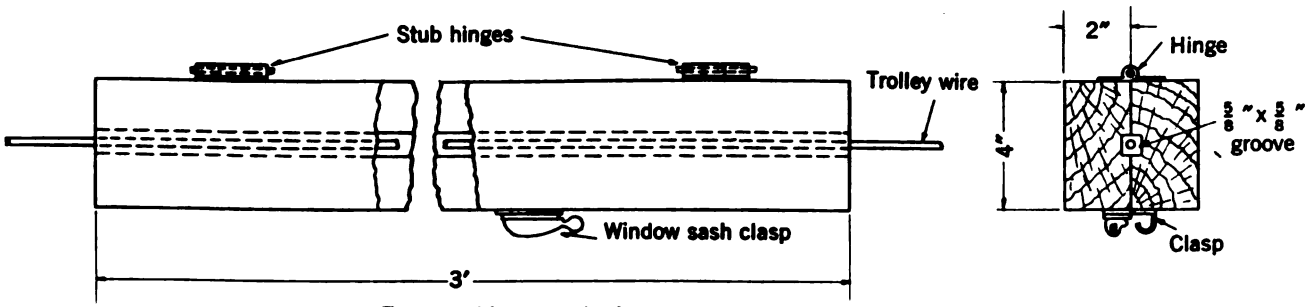
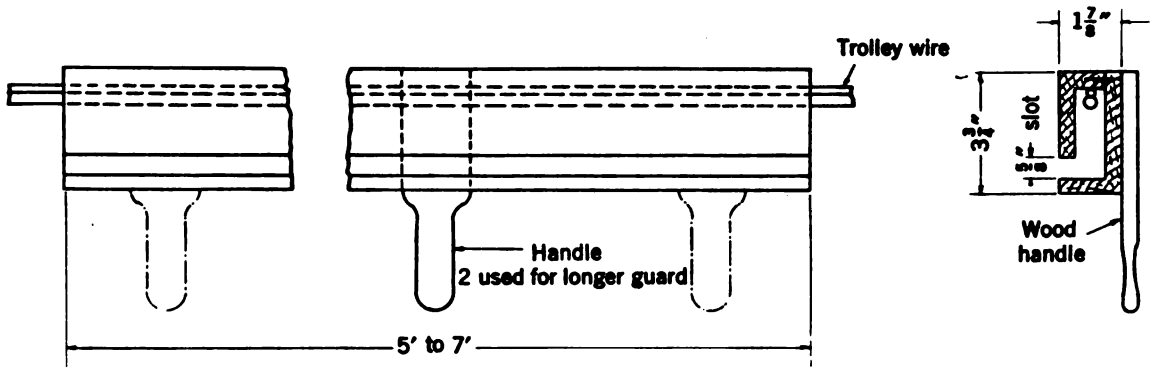
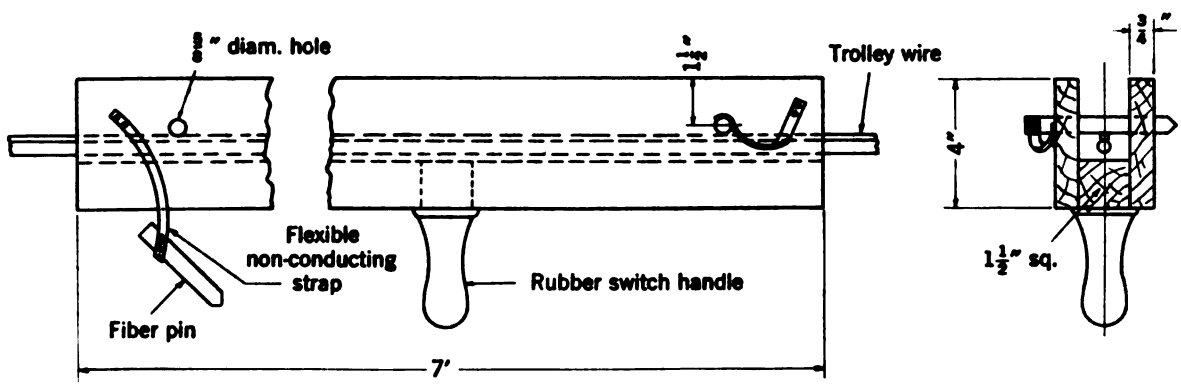


A Type used in a metal mine



B Type used in a metal mine



C Type used in a bituminous mine

Figure 2.—Portable or temporary guards.

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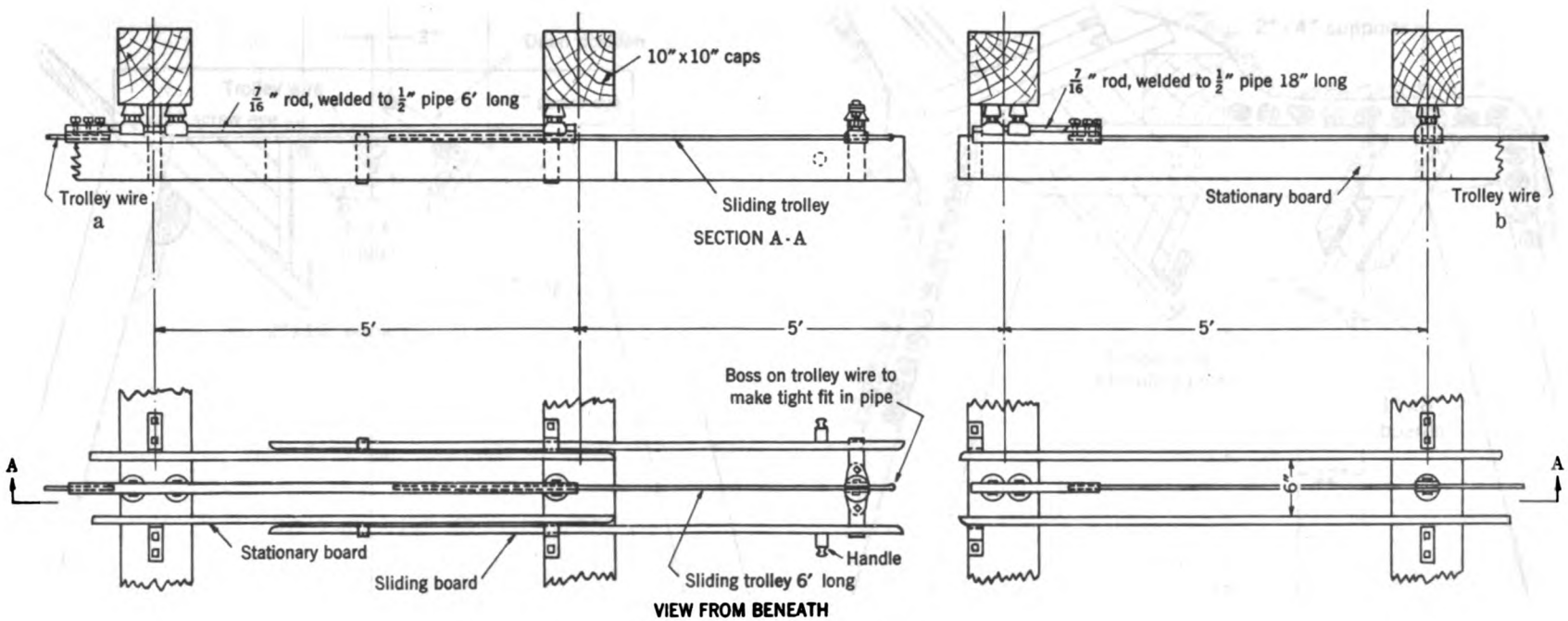

Figure 3.—Sliding guard and safety gap.

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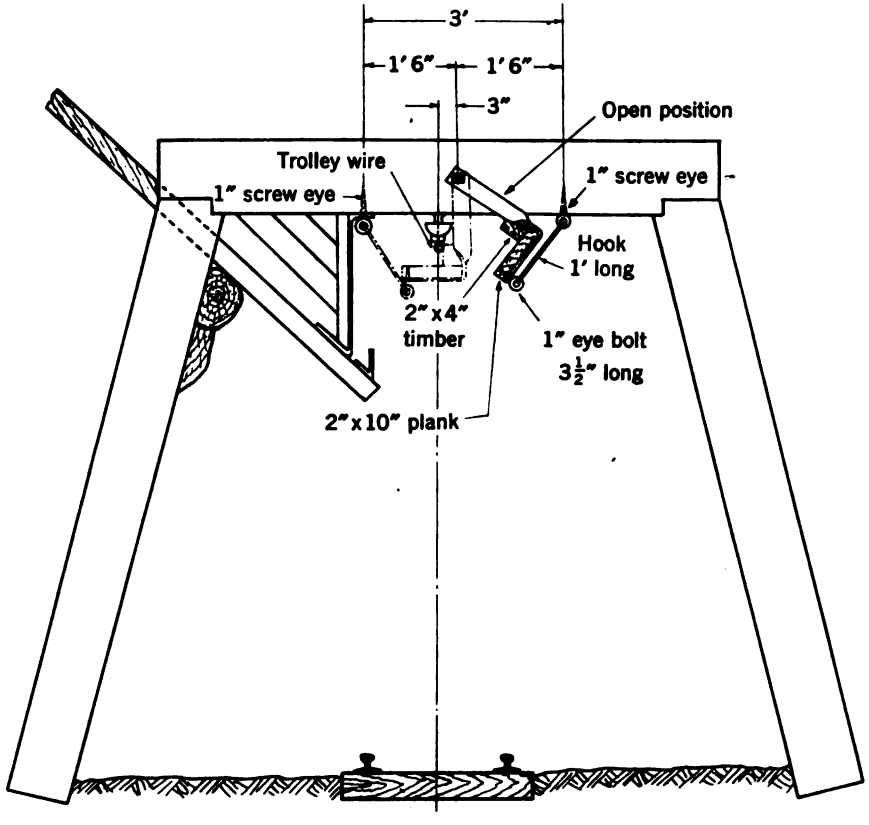

Figure 4a.—Swinging guard.

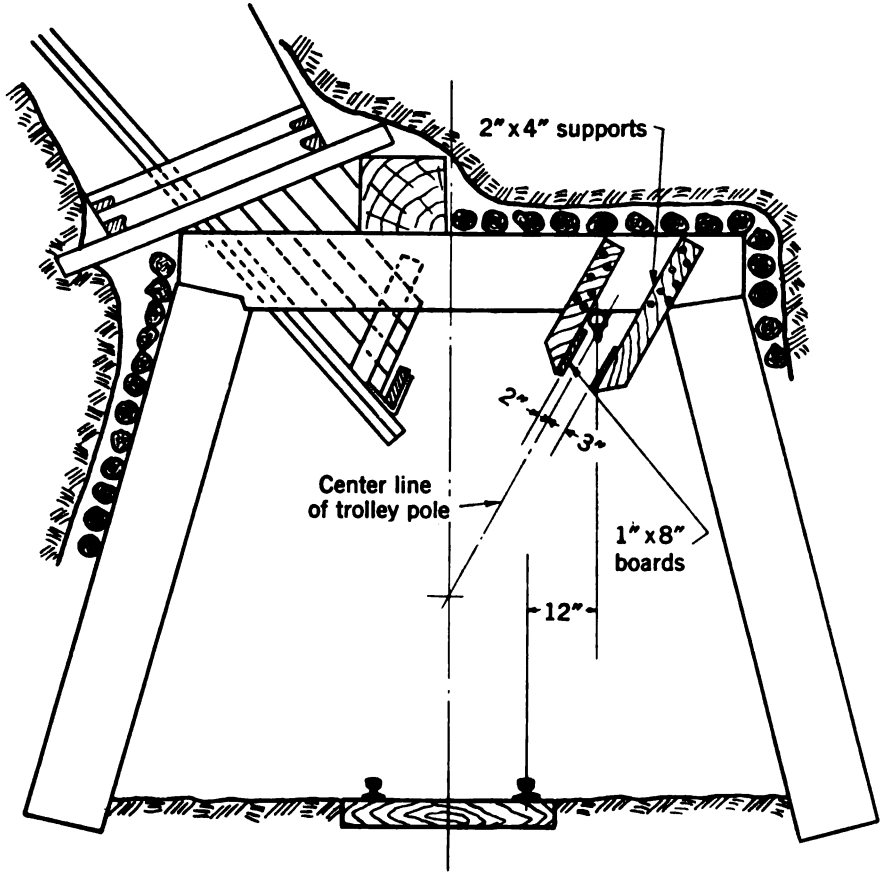

Figure 4b.—Inclined guard.

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wire after the latter has been passed through the 5/8-inch slot in the side. One or two handles, depending on the finished length of the guard, are attached for convenience in handling it.

A third portable guard is shown as type C in figure 2. This is a trough-shaped wood guard that can be suspended from the trolley wire by means of two fiber pins attached to the guard by flexible straps to prevent loss. The disadvantage of the portable guard is that it has to be removed and replaced each time a locomotive has to pass. Eventually, it may become too bothersome and then will not be used unless insisted upon by safety and other officials. The chief merit of the portable guard lies in the fact that as it is not attached to roof or timber, it is not subject to damage or displacement by roof movement, crushing timbers, etc. Hence, its value as a guard would remain unimpaired, whereas a fixed guard might require constant repairing and renewal.

A trolley wire can be an obstruction at chutes in some metal mines, and guards would only complicate matters further. One obvious solution is an arrangement permitting removal of the trolley wire while ore or rock is being drawn from the chute. A method of accomplishing this is illustrated in the February 1932 issue of the Mining Congress Journal.9/ Figure 3 is an adaptation of one given in that publication. In this arrangement, the trolley wire terminates on each side of the chute, leaving a gap of suitable length immediately in front. This gap is permanently bridged by an insulated wire suitably mounted out of harm's way so that flow of current in the trolley circuit need not be interrupted. In order that locomotives may pass by the gap, a sliding section of trolley wire is provided for closing the gap. This section telescopes into a piece of 1/2-inch copper pipe at the left when it is necessary to open the gap and work at the chute. In the figure, the copper pipe is shown as welded to a 7/16-inch rod, which in turn is supported by trolley clamps. A shorter piece of copper pipe on the other side of the gap is supported in a similar manner and serves as a socket to receive the free end of the sliding section of trolley wire when the gap is closed. The trolley hanger that holds this free end of wire is mounted on a bracket, to which are fastened trolley guard boards that slide in suitable brackets attached to the stationary guard boards. Thus, the sliding section of trolley wire is continuously guarded, as the sliding boards move with it.

The article10/ already mentioned also describes two other guards specially designed for installation at chutes in metal mines. These are shown in figures 4a and 4b. The first of these is a trough-shaped member consisting of a piece of 2- by 10-inch plank along the edge of which is fastened a piece of 2- by 4-inch timber. The trough is supported by hinges of 2-1/2- by 1/2-inch iron so placed that the trough can be swung to cover the trolley wire completely while loading from the chute is in progress. When loading is completed, the trough can be swung aside to permit the

9/ See footnote 7.
10/ See footnote 7.

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passage of the locomotive. A hook at the bottom of the trough and screw eyes at each side make it possible to fasten the trough in the open or closed position as desired.

When the trolley-wire is farther removed from the chute, the inclined guard shown in figure 4b has been used. For this type, 1- by 8-inch boards are fastened to 2- by 4-inch supports nailed to the overhead timbers. These supports are set an an angle that will make the lower edge of the lower board extend beyond the vertical center line of the trolley wire. This arrangement involves operating the trolley pole at an angle equal to the inclination of the guard supports.

The guard illustrated in figure 5 is designed to overcome the objection to those types that depend on the alertness and willingness of the men to see that they are in position when needed. This type, as described in Bureau of Mines Information Circular 6546,11/ consists of two hinged members forming a trough that encloses the trolley wire on three sides. The bottom board has a "V" notch cut in each end and it is split longitudinally, so that when a locomotive passes its trolley pole enters the "V," thus separating the two halves and permitting the trolley wheel to proceed without interference. When the trolley pole leaves the guard at the opposite end, the two halves close by gravity. Thus, the guard may be said to be automatic in action. Operation of locomotives at low speeds past this guard is probably advisable to avoid possible damage to the guard.

Trolley wires at both sides of doors have been guarded in several ways. A method frequently employed in bituminous coal mines is illustrated in figure 6a. In this the guard is continuous through the doorway at the upper right-hand corner, and the door is notched so that as it swings open and shut it will clear the guard boards. Figure 6b shows another continuous guard through a doorway. A two-section door is shown, the left section of which is notched so that it will swing without interference with the guard boards. The boards fastened centrally underneath the upper part of the door frame serve to close most of the opening, which otherwise would permit considerable leakage of air. The two-section door has an advantage over the single door, in that by using the section away from the trolley wire, it is not necessary for men to cross under the wire when opening the door, as is generally the case.

Guards of Material Other Than Wood

The one great objection to wooden boards as a material for the construction of trolley guards is its tendency to splinter when struck sharply. In fact, some companies have ruled it out on that account. One engineer stated that because of a "near-serious accident," his company has discontinued the use of boards.

Warping is another disadvantage that may give rise to trouble in guards of ordinary wood. Should the guard warp in one direction, there may be too much space between it and the wire. If it warps in the opposite direction,

11/ See footnote 8.

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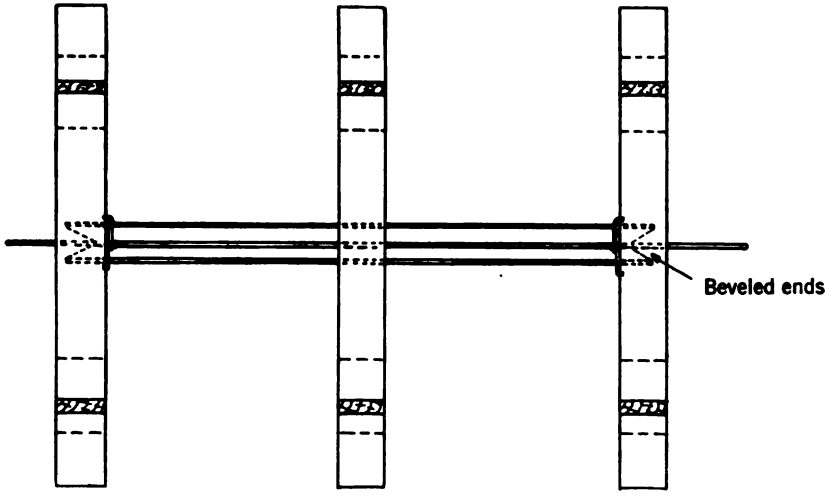

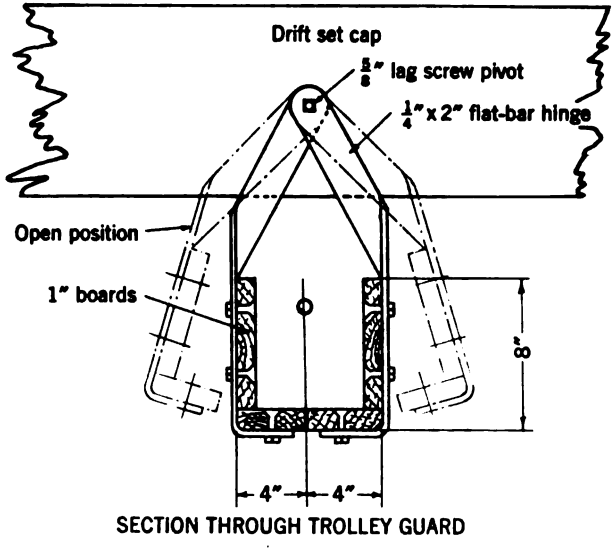

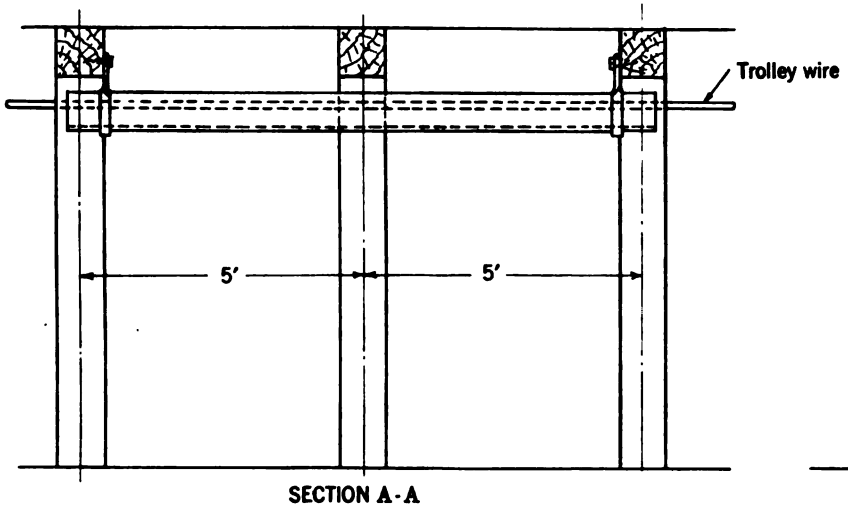

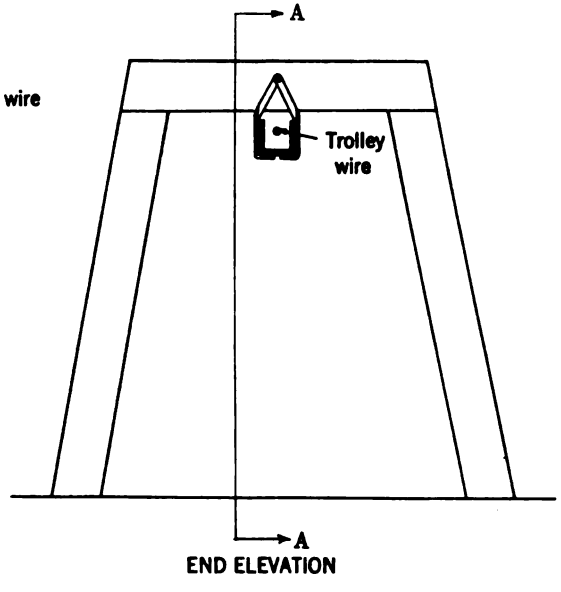

Figure 5.—Self closing trolley guard

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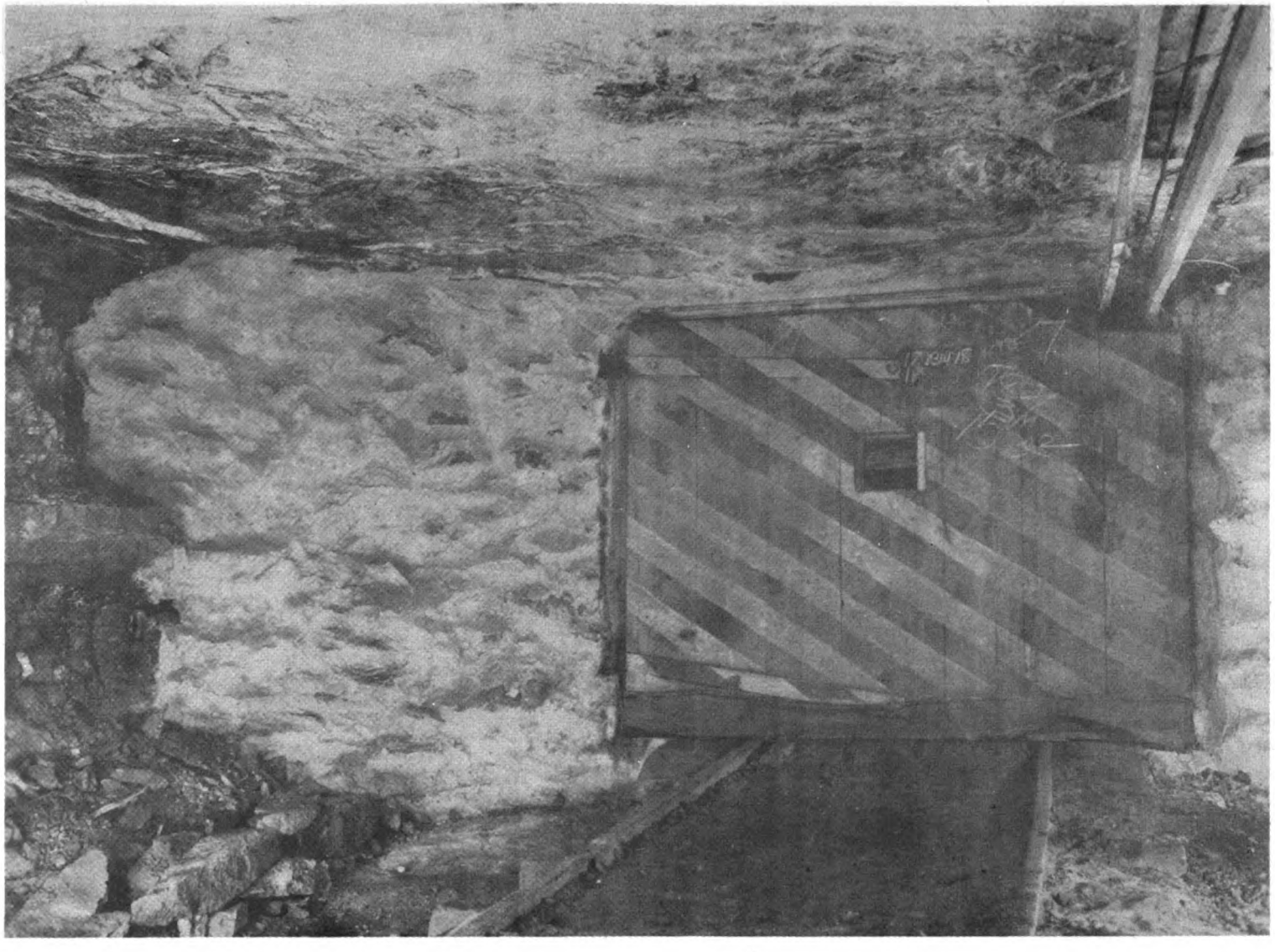

FIGURE 6a.- Trolley guard at mine door.

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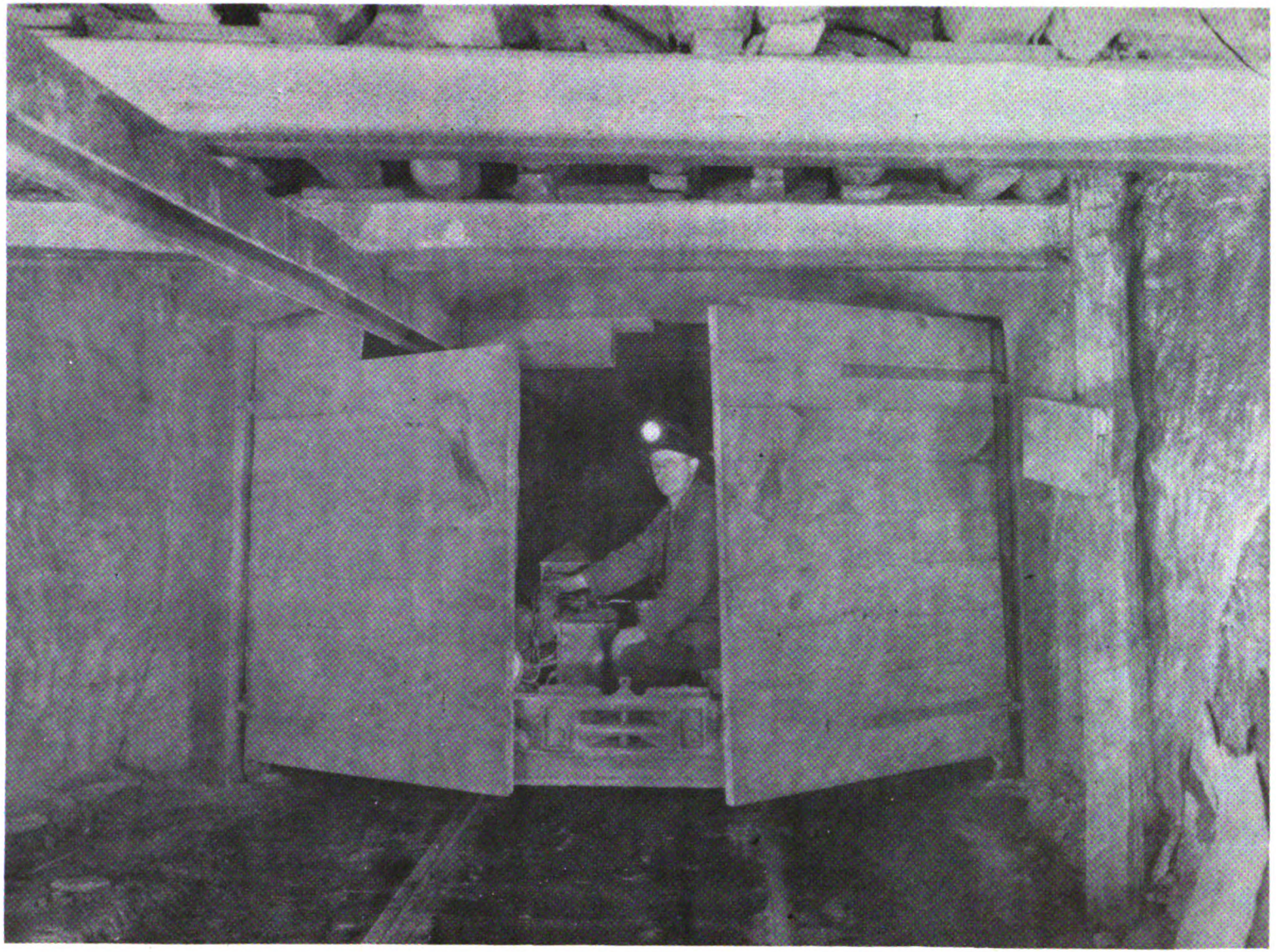

FIGURE 6b.- Trolley guard at two-section door.

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contact with the wire may result and produce a fire hazard through leakage of current through the moist wood. Furthermore, with the board close to the wire, there is likelihood that the current collector will be deflected from the wire as the locomotive passes by.

Therefore, such materials as brattice cloth, fire hose, rubber sheeting, conveyor belting, and hard-pressed board have been employed in an effort to obtain guards without the foregoing objectionable features.

Brattice cloth. - One method of using brattice cloth guards is to nail strips of suitable width to wooden pegs in the roof. Another method is to hang the cloth over messenger wires parallel to the trolley wire. Objection to the brattice-cloth guard has been raised by those who hold that it does not have sufficient insulating qualities, expecially when it becomes more or less saturated with moisture from the mine air or from roof drippings. On the other hand, one advocate of brattice-cloth guards considers that contact with the cloth or with ravelings will serve as a warning through the slight shock or tingling sensation produced when slightly damp cloth is brought into contact with the wire at the same time that it touches the skin. However, if the cloth is wet, a serious shock could be sustained.

Conveyor belting. - In a mine of one of the progressive coal-mining companies, rubber conveyor belting cut into strips 4 or 5 inches wide was used as trolley-guard material. The strips were mounted on a commercial support; that is, the strips were drilled and suspended from the bolts in the manner described as optional for the types F and G hangers shown in figure 1. In addition to possessing excellent insulating qualities, the conveyor belting is free from the objection of splintering and has the necessary stiffness to retain its position with respect to the trolley wire.

Fire hose. - Another material used extensively in the past was discarded fire hose. To install it, one of the creases formed when the hose is flattened, was slit for the length of the hose. At each hanger, the other crease was drilled to admit the boss at the top of the trolley-wire clamp, so that the hose might rest on top of the clamp. Hose too limp to be self-supporting between hangers was supported at suitable intervals by means of short pieces of wire or cable reaching up to a messenger cable above the trolley wire. Several methods were devised to keep the ends of the hose open to permit the trolley wheel to enter freely. In one mine this was done by making an arc-shaped spreader from a piece of strap copper or other suitable metal and riveting it to the outside of the hose at its end. Heavy copper wire has been used instead of strap by making a hook in each end of the wire and pinching the hooks over the edge of the hose, so that the latter is gripped and held tightly. In this case, the main part of the wire is on the upper side of the hose and holds it open for entrance of the trolley wheels or other current collectors.

Rubber sheeting. - More recently (about 1934), rubber sheeting formed expressly for the purpose has supplanted hose as a guard material. One style consists of a strip 9 inches wide and 3/32 to 1/8 inch thick, in which one or two layers of fabric were imbedded. This is folded lengthwise

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in the center and placed as an inverted "V" over the trolley wire in the same manner as the fire hose, a hole being punched at the fold for each trolley-wire clamp. This permits the guard to rest upon the trolley wire and the lower edges are then about 1-1/2 to 2 inches apart. When passing under the guard at right angles to the track, tools, supplies, or miners' caps that come against the guard cause it to turn or bend about the trolley wire as an axis and thus afford protection against direct contact with the wire. However, if a person is directly under the wire and raises his head, the guard may spread open, expecially if he wears a cap having smooth outer surfaces, or it may be raised until the wire is exposed.

Several methods have been employed to insure that the ends of this type of guard are kept open sufficiently to allow the trolley wheel or shoe to enter freely. The simplest method is to terminate the guard at a hanger, and then pressure on the guard material between the hanger and trolley clamp causes the material to remain flared open. At doorways, the guard is split at the fold for several inches. The ends are then spread apart slightly and nailed to the doorframe above the trolley wire. The rubber, being flexible, is easily pushed aside by the door as it opens and closes, and the guard continues to be effective at any position of the door.

Two objections have been raised against rubber guards of this type. The first is that when the trolley pole is reversed or the collector accidentally leaves the wire, it is sometimes difficult to get the collector back up between the sides of the guard. Rather than experience this trouble when reversing direction of travel, the motorman may decide to proceed without reversing his pole, and thus the undesirable practice of "back-poling" may be onccuraged.

The second objection is that oil and grease from the current collector can be deposited within the guard, thereby adding to the fire hazard.

With a view of overcoming these objections, various types of supports have been developed commercially. One of these (type K, fig. 1) is designed to keep the rubber sheeting entirely out of contact with the trolley wire. It has two hooks supported ty two sheet-metal stampings a, that form a clamp for attachment to the trolley wire. The stampings are insulated from the hooks, so that no live parts will be exposed outside of the guard. Strips of rubber sheeting 5 inches wide are hung from the hooks as indicated, the supports being spaced at intervals of about 6 to 8 feet along the wire. A variation of this was to use messenger wires to support 6-1/2-inch strips on each side of the wire.

Two other types of hangers or supports for rubber guards are shown in figure 1 (L and M). These also are steel stampings and clamp on the trolley wire at intervals of about 6 feet; but instead of supporting two separate strips, one strip 12 inches wide is scored lengthwise with 2 parallel lines centrally spaced 2-1/2 inches apart so as to hang like an inverted rectangular trough over the supports. As the supports are clamped on the wire, the guard is essentially in contact with the wire at each support.

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Satisfactory performance of any guard material, whether it be wood, brattice cloth, hose, or rubber sheeting, depends on definite separation between the trolley wire and that material, not only to allow free movement of trolley wheels and shoes but also to prevent leakage of electricity that might result in fire or shock.

That a certain amount of leakage can occur over the surface of rubber guards has been proved experimentally in the Bureau's laboratory. Various samples were tested, both dry and after different treatments with water. It was found that when the samples were dry, no noticeable leakage took place. However, when the surfaces were moistened either by brief dipping in water or by hours of immersion, then leaking did occur.

The principal factor affecting leakage apparently is the kind of finish given the surfaces of the rubber. Samples with roughened surfaces retained moisture more readily than samples with a smooth waxlike finish, and this probably explains why greater leakage was obtained with the former than with the latter. Where the fabric is exposed at the edges of the rubber sheeting, moisture is held by absorption and adds to the leakage. Thus, one sample without smooth-finished surfaces gave readings of 200 to 250 volts along the bottom edges immediately after removal from a bath of mine water, the voltage on the support representing the trolley wire being 550. However, after being allowed to dry in air for 1 hour, the voltage reading was reduced to zero. Similarly, another sample gave readings of 100 to 250 volts along the bottom edges immediately after 29 hours' immersion in water for a voltage equivalent to 500 on the trolley wire. At the same time, voltages of 100 to 125 were read along the outside surfaces of the sample. For a trolley-wire voltage of 250, voltages of 75 to 100 were read along the bottom edges and 40 to 50 on the outside surfaces. It was found difficult to moisten the surfaces of a wax-finished sample. Even after 24 hours' immersion in tap water, the maximum leakage obtained immediately after removal from the water was 30 volts along the lower edges for a trolley-wire voltage of 700. The leakages at 250 and 500 volts were proportionately less.

Hard-pressed board. - A coal mine in a midwestern State has been using "hard-pressed board"[12/] in strips 1/8 inch thick, 6 inches wide, and 8 feet long as guard material.

According to a recent report, this material has given satisfactory service over a period of 7 years. It is sufficiently pliable for installation on curves and, being without grain, does not present the hazard of splintering.

Cost of Guards

The cost of making and installing trolley guards will vary according to the type adopted and the local roof and other conditions. With some types, the item of labor will be comparatively high - if, for example,

12/ Coal Age, Hard-Pressed Board Guards New Orient Trolleys: Vol. 42, April 1937, p. 164.

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the strap-iron hangers are forged at the mine. By using commercial hangers, such as shown in figure 1, the labor charge will not be so great.

In the past, costs of installation have varied from 15 to 57 cents per foot. The cost of labor and materials under wartime conditions is not a true criterion for costs in normal times and accordingly no attempt will be made here to give present-day costs.

Whatever the expense may prove to be, it will not be so high but that it can be fully justified when the guard is a means of saving life.

Maintenance

The best design of trolley guard may be as bad as or even worse than none at all if it is not kept in good condition. Like any other safety device adopted in a mine, it must be inspected regularly and be kept in working order if its protective value is not to be lowered. Observations underground indicate that guards are often neglected. In some mines visited, the board was on one side of the wire but not on the other. Sometimes broken boards with sharp, splintered ends protruding are allowed to remain in their hangers. The greatest value of a guard is in warding off contact that might otherwise be made through failure to realize the presence of a live wire; but if a man must be on the alert to protect himself against injury from a neglected guard, he can about as easily see that he does not come against an unguarded wire. It is important, then, that once guards have been found necessary and have been put in place, they are not allowed to deteriorate to the extent that they themselves constitute a hazard. When guards are made of wood, warped and broken or splintered boards should be replaced immediately by straight, whole ones; otherwise, not only will the efficiency of the guard be impaired, but there will also be danger that the trolley wheels will deflected off the wire or will catch on some part coming in their pathway. For the same reason, all bolts and screws required in fastening or supporting guards should be kept tightly in place. Because of possible fire hazards, no guard material should be permitted to remain in contact with the trolley wire. Therefore, any sheet rubber or hose having a tendency to stretch should be watched carefully to see that it does not sag against the wire.

Roof and floor conditions, especially in coal mines, have an important bearing upon the maintenance of trolley guards. Falls of roof coal and slate may damage the guards and dislodge or loosen hangers and supports. Likewise, guards at chutes in metal mines may be subject to damage by flying pieces of ore. A heaving bottom might affect the alinement of the track with relation to the wire, which would result in difficulty in keeping the trolley wheels from leaving the wire and striking the guard, particularly if derailment of locomotives follows. The use of kinked wire also causes wheels to jump off, and worn-out wheels and harps can produce the same results.

Adequate maintenance can be assured only through careful, systematic inspection at frequent intervals. In this way, minor defects can be

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discovered and corrected and worn or missing parts can be replaced before serious trouble requiring major repairs can develop.

Discipline

Lack of discipline can be another factor affecting the safety of mine workers. For instance, if a rule against "back poling" - that is, running locomotives with the trolley pole in the leading instead of in the trailing position - is not in effect or is not enforced, unnecessary damage to guards, hangers, etc., will follow almost inevitably. Again, if men are permitted to travel where they choose instead of following manways or other passageways expressly set aside and designated to keep them away from live wires and dangerous places, resulting accidents are chargeable to failure to exercise proper supervision. In the failure to enforce wearing of "hard" hats, protection against head contacts with trolley wires is sacrificed. Another rule of discipline is to make certain that men sit on the side opposite the trolley wire when riding in open cars.

SUMMARY

The foregoing discussion of trolley-wire installations and their guarding may be summarized briefly as follows:

1. Personal contact with trolley wires can be prevented in a measure by installing the wires in correct relation to the track and passageways.

2. Compliance with State laws and with approved safety standards or rules covering guarding of trolley installations will furnish additional protection against accidental contact.

3. Guards should be chosen with special reference to the applicability of their materials and construction to conditions at the places where they are to be installed.

4. The cost of installing trolley guards will vary considerably with the length and type of guard selected as well as local conditions such as the nature of the roof material. Present-day costs are not given, because prices of material and labor under wartime conditions are not a true measure of costs during normal times.

5. Adequate maintenance of the trolley system as well as of the guards is highly essential if the guards are to be kept effective.

6. Disciplinary measures should be adopted to prevent unsafe practices such as back-poling.

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